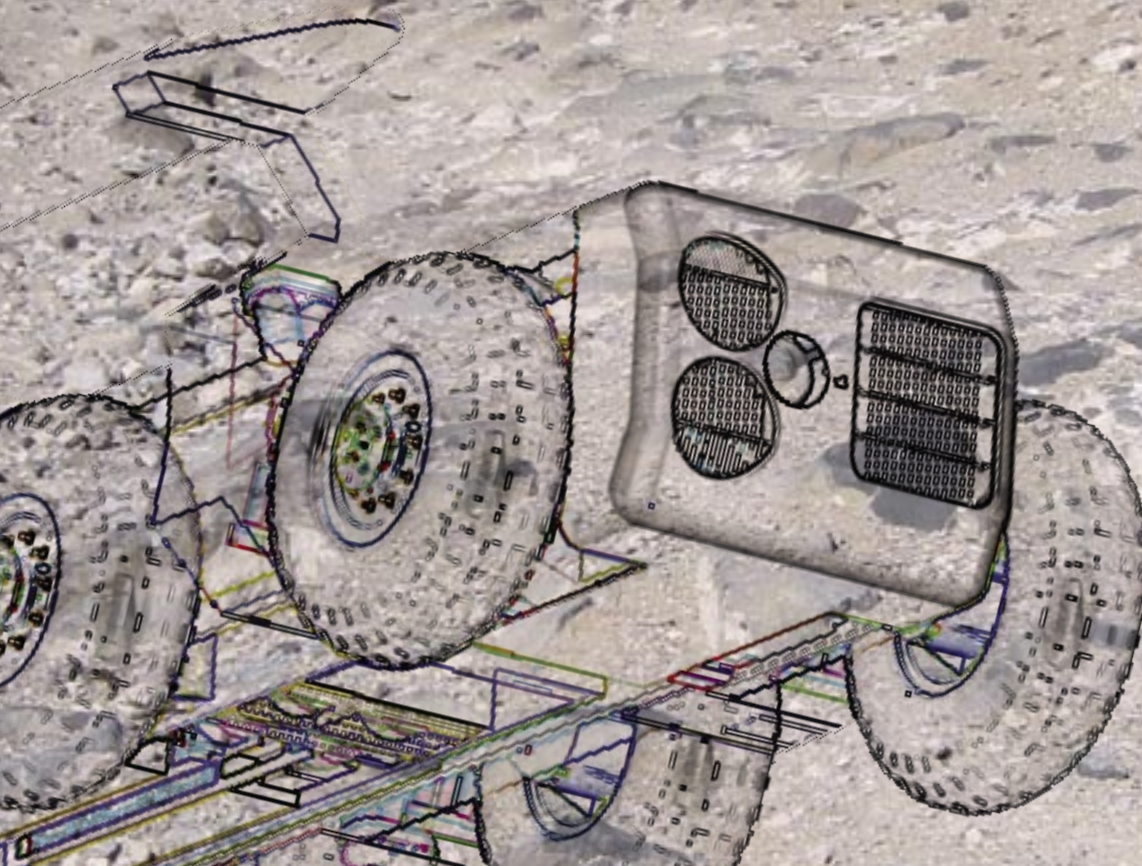


Testing American Ingenuity in Autonomous Vehicle Design

# THE DARPA GRAND CHALLENGE

COMMEMORATIVE PROGRAM

MARCH 8 - 13, 2004



In Association With





# ***A Message from Dr. Anthony Tether***

***Director of the Defense Advanced Research Projects Agency (DARPA)***



On behalf of all Grand Challenge organizers, I would like to thank the teams, elected officials, community leaders, spectators and members of the media who have joined us for this truly unique event.

Last year, more than 450 people from a wide range of organizations, backgrounds, and areas of the country and the world were in Los Angeles for the Grand Challenge competitors' conference. They were intrigued by the idea of competing for a \$1 million prize and a place in history, and committed their talents and passions to the DARPA Grand Challenge.

The teams in this final field reflect the fresh thinking and enthusiasm we saw at that conference. High school and university students, vehicle manufacturers, garage mechanics, computer programmers, software publishers, sensing experts, off-road racers, entertainment industry insiders and robotics enthusiasts are among those represented on the teams here this week, as well as those who valiantly tried hard but did not make it this far.

They are united in the quest to develop a new generation of autonomous robotic ground vehicles that some day soon will save the lives of men and women in our armed forces by performing hazardous tasks on the battlefield.

After more than a year of hard work by this gifted group of innovators and trailblazers, the time has finally come.

Let the Grand Challenge begin.

*Anthony J. Tether*

# **DARPA's Heritage of Innovation and Results**

The Grand Challenge is the latest chapter in the Defense Advanced Research Projects Agency's (DARPA's) long history of breaking new ground by pursuing research and technology where the risk and payoff are both very high and where success may provide dramatic advances for traditional military roles and missions.

"DARPA has always attracted people who can look at problems differently and find creative ways to solve them," said DARPA Director Dr. Anthony Tether. "The Grand Challenge creates a way for us to reach out and find people who will help us advance the development of autonomous robotic ground vehicle technology."

DARPA was established as an agency of the U.S. Department of Defense (DoD) in 1958 as America's first response to the Soviet launching of Sputnik. Since that time, DARPA's mission has been to assure that our country maintains a lead in applying state-of-the-art technology for military capabilities, and to prevent technological surprise from our adversaries.

## **Unique Structure and Culture**

DARPA's many contributions to national security are the result of a unique structure and culture that encourages original and unconventional thought. The Agency is small and flexible, and enjoys substantial autonomy and freedom from bureaucratic impediments.

Its technical staff is drawn from world-class scientists and engineers, with people from industry, universities, government laboratories, and federally funded research and development centers. Technical staff are assigned to DARPA for three to five years and rotated to assure fresh thinking and perspectives.



***DARPA's freedom  
to act quickly  
and decisively  
with high-quality  
people has paid  
handsome dividends  
for DoD in terms  
of revolutionary  
military capabilities.***

Program Managers, the heart of DARPA, are selected to be technically outstanding and entrepreneurial. The best DARPA Program Managers have always been freewheeling zealots in pursuit of their goals. Management is focused on good stewardship of taxpayer funds, but imposes little else in terms of rules. Management's job is to enable the Program Managers.

### ***Strong Return on Investment***

DARPA's freedom to act quickly and decisively with high-quality people has paid handsome dividends for DoD in terms of revolutionary military capabilities.

DARPA was the driving force behind technology advancements for the development of stealthy aircraft, including the prototypes for today's stealth fighter, the F-117, and bomber, the B-2. More recently, DARPA research led to the creation of unmanned aircraft such as the Global Hawk and the Predator, which now carry out surveillance, reconnaissance and precision bombing missions.



Perhaps the most famous of all DARPA technology development programs is the Internet, which began in the 1960s with the development of ARPANet and its associated TCP/IP network protocol architecture. Global positioning systems and night vision are other examples of technologies fostered by DARPA research that have migrated to the marketplace.

### ***New Solutions for a Changing World***

DARPA continually changes much of what it is doing in response to the different national security threats and technological opportunities facing the U.S. As a result of this constant strategic reassessment, DARPA currently is emphasizing research in eight strategic thrusts:

- *Detection, Precision ID, Tracking and Destruction of Elusive Surface Targets*
- *Location and Characterization of Underground Structures*
- *Networked Manned and Unmanned Systems*
- *Robust, Self-Forming Tactical Networks*
- *Assured Use of Space*
- *Cognitive Computing*
- *Bio-Revolution*
- *Force Multipliers for Urban Area Operations*

DARPA's ability to adapt rapidly to changing environments and to seek and embrace opportunities both in technology and in processes, while maintaining the historically proven principles of the Agency, makes DARPA a unique R&D organization.

# The **Grand Challenge**

The DARPA Grand Challenge is a field test that requires autonomous robotic ground vehicles to successfully navigate a course from Barstow, CA to Primm, NV on Saturday, March 13, 2004.

The course will cover approximately 200 miles of off- and on-road terrain that will be cleared of non-participating vehicles. Competitors' entries must be unmanned, autonomous ground vehicles, and cannot be remotely driven. Boundaries define the course, and vehicles that go outside of them will be disqualified. Each vehicle will be trailed on the course by a manned control vehicle equipped with an emergency stop system to prevent collisions and other unsafe situations.

Prior to the Grand Challenge main event, there will be a qualification, inspection and demonstration (QID) event March 8-12 at California Speedway in Fontana, CA. Teams will undergo a series of tests to determine the ability of the systems to autonomously navigate and avoid obstacles, as well as thorough inspections to ensure that they meet safety and performance requirements. At the conclusion of the QID event, DARPA will announce the final field of teams that will compete in the Grand Challenge.

The day after the Grand Challenge, DARPA will award a cash prize of \$1 million to the winner – the team that most quickly completes the course in less than the 10-hour time limit. If no teams finish, no prize will be awarded.



## Schedule of Events

### Qualification, Inspection and Demonstration (QID) Event *California Speedway (Fontana, California)*

#### **Monday, March 8, 2004**


9:00 am	Opening Ceremony
10:00 am	Kick-Off News Conference
1:00 pm - 5:00 pm	QID Begins

#### **Tuesday - Friday, March 9 - 12, 2004**

8:00 am - 5:00 pm	QID Continues
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\* Registration is not necessary for spectators of the Grand Challenge's QID, start and finish line areas. Dinner and celebration events are ticketed activities.

\* Spectators must stay within the designated areas and behind all barriers indicated. Only credentialed media are allowed in media access areas.



***Entries must be unmanned,  
autonomous ground vehicles  
that cannot be remotely driven.***

### **The Grand Challenge**

*(Barstow, CA - Primm, NV)*

#### **Saturday, March 13, 2004**

##### ***Start Line: Barstow, CA***

4:00 am	Media Registration Begins
5:00 am	Press Briefing
6:00 am	Opening Ceremony
6:30 am - 8:30 am	Vehicles Begin Departing

##### ***Finish Line: Primm, NV***

6:30 am - 8:30 am	Live Satellite Feed from Start
9:00 am - 6:00 pm	Exhibit Area Open
6:00 pm	Press Briefing
7:00 pm	Finish Line Celebration

### **Recognition and Awards Presentation**

*(Primm, Nevada)*

#### **Sunday, March 14, 2004**

9:00 am - 6:00 pm	Exhibit Area Open
6:30 pm	Dinner Ceremony, Check Presentation

## *The Inspiration*

As America enters an era of unprecedented challenges to our national security, robotics technology offers tremendous potential to help protect our nation and our allies around the world. The DARPA Grand Challenge provides a first glimpse at how autonomous robotic ground vehicles will play an integral role in this effort.

In 2002, DARPA Director Dr. Anthony Tether first proposed the idea of creating a program to reach out beyond the defense contracting community to nontraditional sources for fresh thinking to the still evolving question of how unmanned ground vehicles could become a viable component of America's national defense.

"Our goal was to attract a diverse mix of disciplines and personalities that reflect the innovative spirit of the Grand Challenge program, and we have succeeded in our quest," said Dr. Tether. "By bringing together leaders in business, defense, technology and academia with nontraditional partners in fields such as robotics, entertainment and off-road racing, we sought to develop synergies that would foster new ways of thinking."

### ***Leveraging American Ingenuity***

Charles Lindbergh's first-ever solo trans-Atlantic flight in 1927 was the result of a contest that offered the winner a \$25,000 cash prize for achieving a first in aviation history, and the DARPA Grand Challenge offers a 21<sup>st</sup> century equivalent of the historic flight of the Spirit of St. Louis.

Every day all across America, modern-day Lindberghs are developing technologies that offer the potential to help foster the development of autonomous robotic ground vehicle technology. Unfortunately, many of these ideas do not make their way to the DoD because they originate outside the normal defense contracting channels and in people's garages, classrooms, laboratories, racetracks and workshops.

DARPA envisions the Grand Challenge for autonomous robotic ground vehicles as the first in a series of similar challenges related to various national security issues designed to attract new ideas and information sources for technology.



## Congressional Authority

The U.S. Congress also has played an integral role in creating the mechanism for establishing the Grand Challenge's \$1 million cash prize, and making the development of unmanned ground combat vehicles a top priority for America's armed forces. Two provisions of law establish the program's mandate:

"The Secretary of Defense, acting through the Director of the Defense Advanced Research Projects Agency, may carry out a program to award cash prizes in recognition of outstanding achievements in basic, advanced and applied research, technology development, and prototype development that have the potential for application to the performance of the military missions of the Department of Defense."

*-National Defense Authorization Act for Fiscal Year 2003 (10 USC, Sec. 2374a)*

"It shall be a goal of the Armed Forces to achieve the fielding of unmanned, remotely controlled technology such that...by 2015, one-third of the operational ground combat vehicles are unmanned."

*-Floyd D. Spence National Defense Authorization Act for Fiscal Year 2001 (P.L. 106-398 Sec. 220)*



## Ground Force of the Future

Unmanned aerial vehicles have advanced to the point where they are mainstays in America's national defense. The Predator and the Global Hawk both carried out numerous reconnaissance and surveillance missions during Operation Iraqi Freedom, and the Predator also performed precision airstrikes.

Their counterparts on the ground remain a work in progress, and the DARPA Grand Challenge for autonomous robotic ground vehicles reflects an effort by the DoD to further develop the technology. Eventually, these future unmanned ground vehicles will operate in concert with manned systems to form an integrated fighting force. The goal is not simply to replace people with machines, but to team people with robots to create a more capable, agile, and cost-effective force that lowers the risk of U.S. casualties.



# ***The Road to the Grand Challenge***

The Grand Challenge already has gained renown for its talented and diverse field of teams, rugged 200-mile course, thorough rules and procedures, weeklong series of events, and widespread visibility. This achievement is the culmination of nearly two years of work by program organizers and participants.

“Just like any major military operation, the Grand Challenge required an incredible amount of planning and attention to detail,” said Col. Jose Negron, DARPA’s program manager for the event. “We have an extremely talented and dedicated team of DARPA staff and contractors that has put an enormous amount of work into ensuring the success of the Grand Challenge.”

## **Competitors’ Conference**

The first official public event for the Grand Challenge came on February 22, 2003, when nearly 500 prospective participants gathered at the Petersen Automotive Museum in Los Angeles for a competitors’ conference.

Attendees received a series of briefings on all aspects of the Grand Challenge, including a program overview, rules, vehicle requirements and the course. Following the briefings, a teaming forum helped facilitate partnering between complementary competitors and match up suppliers of various technologies and services with vehicle designers. Strong attendance at the competitors’ conference and the high profile media coverage it generated offered a first glimpse at the widespread interest in the Grand Challenge that would build over the next year.



Grand Challenge Program Manager Colonel Jose Negron, USAF, (center) reviews Grand Challenge details with DARPA Director Dr. Anthony Tether (left) and DARPA Deputy Director Dr. Robert Leheny (right).



SCORE CEO/President Sal Fish (far left) participates in the teaming forum at the competitors’ conference that helped teams with partnering.

***Just like any major military operation, the Grand Challenge required an incredible amount of planning and attention to detail.***

# ***Charting the Course***

## ***Route Development***

Building on the success of the competitors' conference, DARPA then shifted its focus to developing the Grand Challenge course by exploring a variety of routes in the desert between Los Angeles and Las Vegas.

After extensive research and surveying, DARPA's route development team determined that starting in Barstow, California and finishing in Primm, Nevada offered the most viable corridor for the Grand Challenge, and they identified three primary candidates for the route. That set the stage for the exacting process of plotting the waypoints along each route that would allow the vehicles to navigate using their route definition data file.



DARPA Chief of Staff Ron Kurjanowicz conducts a route development debriefing in the Grand Challenge finish line command center in Primm, Nev.

### **Environment and Safety**

The top priority in route development was to emerge with a course that would be not only challenging to the teams, but also safe and environmentally responsible. DARPA worked closely with the appropriate federal, state and local authorities to secure the necessary permits, and underwent a rigorous environmental assessment and approval process with the California and Nevada Bureaus of Land Management (BLM). In order to ensure minimal community and environmental impact, Grand Challenge organizers met with elected officials and community leaders along the route to get their input on the environmental and safety plan for the event.



Sal Fish, Col. Jose Negron and DARPA Grand Challenge Deputy Program Manager Tom Strat conduct a route survey.

A team of more than 100 law enforcement officers, security specialists, BLM rangers, biologists and emergency medical technicians has developed a comprehensive safety and environmental protection plan they will carry out during the Grand Challenge. To support route development and related environmental and safety issues, DARPA also enlisted the expertise of SCORE International, which offers 30 years of experience successfully planning off-road vehicle events in California and Nevada.

### **Tortoise Protection**

Just as Grand Challenge organizers are taking every precaution to ensure safety and environmental protection, they are also going to great lengths to protect one particularly beloved native of the desert. The route passes through areas that are the habitat of the desert tortoise, which is listed as a threatened species by California, Nevada and the federal government.

For the past several months, a team of desert tortoise biologists has been assessing the tortoise habitat along the route and providing input on mitigation efforts. In the days leading up to the Grand Challenge, the biologist team will perform a series of tortoise sweeps, and temporarily protect some of them with pens that will be removed after the event. Biologists will be stationed strategically along the route during the Grand Challenge to remove tortoises that unexpectedly wander onto the course based on direction received from a biological coordinator stationed in the command center.





### ***The Ultimate Test: A Rugged Route between Los Angeles and Las Vegas***

The 200-mile Grand Challenge route covers some of the most forbidding country in the United States. Competing vehicles will face a supreme test of their strength and durability as they run a gauntlet of obstacles and terrain types, including:

Natural obstructions

Brushland

Dry lakebeds

Hard packed trails

Ridge tops

Rocky trails

Sand

Unsurfaced roads

Paved roads

Overpasses

Underpasses

Water

Cattleguards

Erosion gullies

Rockfalls

Steep slopes

## \$1 Million Prize Offered by Pentagon Agency

"Work around the clock. Spend tens of thousands of dollars. (At least.) Do the impossible. And get well rewarded by Uncle Sam. Dozens of small groups are driving to do that by March 13, 2004. Show up with a vehicle that can direct itself from Los Angeles to Las Vegas in 10 hours — sorry, no human help allowed — and you could win serious bragging rights. Oh, and a million dollars cash."

-MSNBC

## Robots Get Ready to Run

"Years ago, DARPA set out to invent a new type of robotic technology virtually from the ground up. Congress had set a goal that one-third of the Army's ground combat vehicles would be unmanned by 2015. So far, in dealing with the established process, there hasn't been much success. Two defense contractors were unable to solve the problem, so DARPA came up with a unique idea: offer a big cash prize with virtually no limits on who could win it. After all, a similar idea led Charles Lindbergh in 1927 to become the first person to fly solo across the Atlantic Ocean."

-Las Vegas Review-Journal

## Robotic Road Trip on a Military Mission

"Teams from universities and small companies, as well as hobbyists, will compete next March in the Grand Challenge, a contest sponsored by the Defense Advanced Research Projects Agency, or DARPA, an arm of the Defense Department. The winning vehicle — if there is one — will be the first to cross the finish line after traversing roughly 200 miles of desert in less than 10 hours without a driver or remote control."

- The New York Times

## Pentagon Looks for Few Good Robotic Vehicles

"DARPA officials hope that some computer whiz kid, some science-fiction fanatic, some junkyard warrior or off-road enthusiast can come up with a way to navigate the 300-mile course in the Mojave desert that will be loaded with obstacles."

-Orange County Register

## No Drivers Wanted

"...the Grand Challenge is the brainchild of the Defense Advanced Research Projects Agency, or DARPA, the \$2-billion whiz-bang shop at the Pentagon that helped create the Internet, Stealth aircraft, 'smart' bombs and the pilotless Predator plane."

-*Los Angeles Times*

## A New Race of Robots

"...DARPA set up the competition to spur progress toward a vehicle that could enter a battlefield with minimal human supervision."

-*Scientific American*

## The Cannonbot Run

"The rules? Each vehicle must be able to drive itself, refuel itself, and make its own decisions. The point? To advance development of military vehicles that can cross minefields and patrol the backstreets of hostile capitals without risking a single American life. The prize? One million of your tax dollars."

-*Esquire*

## Gentle-robots, Start Your Engines!

"What lies behind the contest is the Defense Department's desire to automate many of its ground vehicles, both fighting vehicles and cargo carriers, to reduce risk to life and limb by replacing soldiers on the battlefield when possible."

-*Pittsburgh Post-Gazette*

## Clash of the Headless Humvees

"When DARPA — the Defense Advanced Research Projects Agency, the Defense Department's R&D wing — began cogitating on an ambitious 2001 Congressional mandate to make one-third of the military's ground vehicles unmanned by the year 2015, it decided to throw open the field with the Grand Challenge. Let the academics and garage tinkerers knock themselves out trying to solve the puzzle of off-road robotics. 'Our goal was to jump-start the technology,' says Air Force Colonel Jose Negron, Grand Challenge program director, 'by galvanizing the interest that was out there, especially among people who previously had little or no connection with the government or the big defense contracting companies.' In other words, less *Star Wars*, more *Road Warrior*."

-*Popular Science*

# Sal Fish's **SCORE International** *Helping DARPA Grand Challenge*



SCORE CEO/President Sal Fish

Founded in 1973, SCORE continues today under the direction of CEO/President Sal Fish as the leading sanctioning body in the sport of desert racing and is famous for its flagship event, the legendary Tecate SCORE Baja 1000. SCORE is assisting with route development and logistics support.

“To be asked to participate in a monumental, pioneering event like the DARPA Grand Challenge is an incredible testimony to the reputation SCORE International has built and maintained for over three decades,” said Fish. “For SCORE, helping produce this extreme field test really brings out the red, white and blue in all of us. Being able to contribute to the success of the DARPA Grand Challenge is like giving something back to our country for all our country has done for us.”

Overseeing daily operations for the more than 100 SCORE personnel involved with the ground operations and facility set-up is Paul Fish, SCORE’s long-time Vice President and Sal Fish’s nephew. Paul Fish is actively involved with the purchase and distribution of the massive equipment and supply inventory needed.

In addition to helping DARPA identify and design a route that would be challenging, yet capable of being traversed by vehicles without a human driver, Sal Fish has used his vast expertise in the desert to deal with the numerous government, political, law enforcement, land owners and special interest groups who have been such vital parts of the permitting process.



Fish was also a key player in identifying and securing the use of the start and finish line areas for the DARPA Grand Challenge. Fish helped secure not only the various sites, but also the temporary work facilities, security structures, electrical source, communications access and public safety equipment.



## Setting the Standard: ***The Final Field***

One of DARPA's top priorities for the Grand Challenge was to attract a strong turnout of potential teams from a variety of backgrounds, organizations and areas of the country.

Thanks to DARPA's ongoing recruiting and media outreach effort leading up to the selection process, 106 teams submitted applications expressing their interest. Out of that initial group of applicants, 86 submitted technical papers by the October 14, 2003 deadline. After a rigorous evaluation of technical papers and select site visits, DARPA selected the final field of 25 teams.

"We have clearly sparked the enthusiasm and innovation that makes America great. The teams include students, engineers, inventors and backyard mechanics, with many of them working in their home garages," noted Grand Challenge Program Manager Col. Jose Negron. "These talented participants will bring fresh thinking to autonomous robotic ground vehicle technology for national defense."

Soon after the teams were selected, DARPA conducted a random drawing to determine the starting order for teams at the qualification, inspection and demonstration (QID) event. Teams' starting positions for the Grand Challenge will be determined by the panel of judges based on their performance at the QID.

# AI Motorvators

**Team Name:** AI Motorvators

**Vehicle Name:** *It...Came From the Garage*

**Team Leader:** Chris "CJ" Pederson

**Organization:** AutoIntelligent Systems

**Location:** Los Angeles, CA



## ***In Their Own Words...***

## IT...CAME FROM THE GARAGE

AutoIntelligent Systems' / AI Motorvators' approach is somewhere between a neural net and a brick on the accelerator. We take very seriously the evolution of the automobile as a thinking machine and computer as hot-rod. Our vehicle represents a point of departure toward that end. No matter the outcome of this year's event, we are committed to advancing our vehicle and system capabilities. We plan on continuing to develop and promote next-generation autonomous vehicles using techniques and valuable experience gained during the competition.

## PRIMARY SPONSORS

AutoIntelligent Systems, RADARSAT International, bendymusic.com, Digital Globe, Parthenon Technologies, Trimble

# Axion Racing

**Team Name:** Axion Racing

**Vehicle Name:** Spirit of Kosrae

**Team Leader:** Bill Kehaly

**Organization:** Axion, LLC

**Location:** Westlake Village, CA



## In Their Own Words...

## SPIRIT OF KOSRAE

The Spirit of Kosrae is a street legal American production model 1994 Jeep 4x4 Grand Cherokee. Seating five comfortably, it switches from manual to autonomous control in seconds.

Using sophisticated software design the Axion ArbitratorT easily integrates up to 64 sensors. Integration includes route planning, high definition maps, artificial intelligence, and low-cost design.

Axion Racing has matched every capability of its viable competitors, but at a fraction of their expenditures. Superior coding, planning, individual expertise, and a little luck provide exceptional results.

Using Differential GPS, LADAR, RADAR, SONAR, stereo cameras, servo-actuators, and the Axion ArbitratorT, this DGC vehicle drives itself!



## PRIMARY SPONSORS

Westlake Waters, Inc.

# The Blue Team

**Team Name:** The Blue Team

**Vehicle Name:** Dexterit – Ghost Rider

**Team Leader:** Anthony Levandowski

**Organization:** Robotic Infantry, Inc.

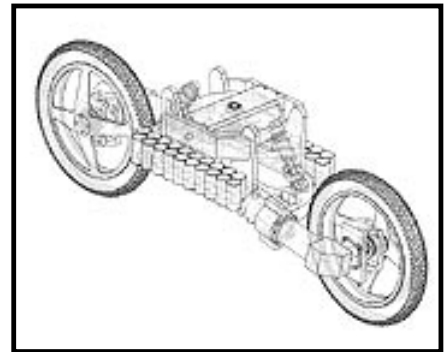
**Location:** Berkeley, CA



## In Their Own Words...

## DEXTERIT - GHOST RIDER

“Dexterit” is the world’s first autonomous single-track vehicle; providing superior off-road mobility. We keep the vehicle stabilized by changing the steering wheel angle through use of our patent-pending technology. A Control Moment Gyroscope (CMG) provides static stability by correcting deviations from vertical while being stopped. There are three different sensing mechanisms for obstacle avoidance on board: a pair of stereoscopic cameras that look for possible paths; a millimeter wave radar to detect objects with ferrous content; and a thermal imaging camera. All are coupled to field programmable gate arrays (FPGA) that looks for moving objects. Go to [www.dexterit.com](http://www.dexterit.com) for more information.



## PRIMARY SPONSORS

Raytheon, AMD, Crossbow, Agilent, Nation Instruments, HaasCNC, Chatsworth, Sandisk, Hobby Engineering

# Digital Auto Drive (D.A.D.)

**Team Name:** Digital Auto Drive (D.A.D.)

**Vehicle Name:** Team D.A.D. Grand Challenge Vehicle

**Team Leader:** Dave Hall

**Organization:** Digital Auto Drive

**Location:** Morgan Hill, CA



## In Their Own Words... TEAM D.A.D. GRAND CHALLENGE VEHICLE

Team D.A.D. Grand Challenge Vehicle is a standard full-sized pickup truck retrofitted with a proprietary Digital Auto Drive (D.A.D.) vision recognition, navigation, and obstacle avoidance system. The D.A.D. vision system utilizes two broadcast quality cameras mounted on top of the vehicle that feed digital images to two high-speed computer chips, which process the image looking for obstacles. Over 30 billion pixels are analyzed each second. This, combined with advanced GPS, dead reckoning, and servo-motor systems controlled by a third computer chip, give the Team D.A.D. Grand Challenge Vehicle its ability to self-navigate. All systems were designed and programmed by Dave Hall, Team D.A.D. captain.



## PRIMARY SPONSORS

Velodyne Acoustics, Inc.

# Palos Verdes High School Road Warriors

**Team Name:** Palos Verdes High School Road Warriors

**Vehicle Name:** Doom Buggy

**Team Leader:** Chris Bowles

**Organization:** Palos Verdes High School

**Location:** Palos Verdes Estates, CA



## In Their Own Words...

The Palos Verdes High School Road Warriors vehicle is an Acura MDX SUV. This vehicle has been modified with Electronic Mobility Controls which will act as the interface between the actual controls of the vehicle and the computers driving autonomously. The interior of the vehicle has been removed and mounting plates, brackets, and wires have been installed for the drive by wire control computer, FFIS, IMU, and other necessary components that will be implemented into the vehicle. Also, the vehicle has been fitted with a trailer hitch carrier which houses our EU 2000 Honda Generator. The car is decked with a full feature light bar, strobe lights, and horn and includes a set of off-road, all-terrain Goodyear tires. With a 256 horsepower, aluminum-alloy 24-valve, SOHC VTEC™ V-6, our MDX is gearing to compete in the DARPA Grand Challenge.

## DOOM BUGGY



## PRIMARY SPONSORS

Honda, Acura, EMC, AIAA, PVHS Booster Club, Goodyear Tires, Family Foundation Scientific Grant, SICK, UCLA, Mathworks, Sysense, Compu Measurement, STI

# Red Team

**Team Name:** Red Team

**Vehicle Name:** Sandstorm

**Team Leader:** Red Whittaker

**Organization:** Carnegie Mellon University

**Location:** Pittsburgh, PA



## In Their Own Words...

Sandstorm is a modified HMMWV with customized suspension, wheels, tires, turbo and actuators for desert driving by computer. Fragile payload is suspended to protect components and to smooth sensor trajectories. Sensors include scanning lasers, stereo cameras and radar. These are stabilized by servo-actuators to eliminate jitter and to point the sensors where Sandstorm intends to drive. GPS, inertial sensing and odometry register the vehicle precisely to intended routes. Computing includes a 64-bit Itanium server, three dual Xeons, and eight embedded computers. These computers process world models, generate autonomous plans and command driving functions.

## SANDSTORM



## PRIMARY SPONSORS

Acumen Systems FLORIDA, Advanced Motion Controls, Alcoa, Aliyance Group, Applanix, ATI, BAE Systems, BF Goodrich, Boeing, Caterpillar, Carnegie Mellon, CM Labs, Crouzet, DriverlessMotorsports.com, Earthlink, Exceltech, Ganassi Racing, Google, Harris, HD Systems, Hutchinson, Intel, Integrated Software, Inc., J&J Truck Bodies and Trailers, Kubota, Lord Corporation, Mechtron, Mellon, Armour Negley, Motion Picture Marine, NATC, Omnistar, Redteam, Rod Hall Team Hummer, SAIC, Seagate, Space Imaging, S - B Equipment Service, Starband, Terrasim, The Robotics Foundry, Trimble, Vicor, Visual Intelligence, [www.redteamracing.org](http://www.redteamracing.org), Yamaha, Zombie

# Rob Meyer Productions

**Team Name:** Rob Meyer Productions

**Vehicle Name:** The Coyote

**Team Leader:** Rob Meyer

**Organization:** Rob Meyer Productions

**Location:** Tucson, AZ



## In Their Own Words...

## THE COYOTE

The "Coyote Autonomous Vehicle System" was named so because of the task it is designed to do – to wander across the desert sniffing out the easiest way – reminiscent of a frequent sight in Tucson, a coyote.

Technically, the Coyote is probably similar to some of our competitors' entries. It uses a combination of Laser Ranging, Sonar, GPS, and Video to find its way. Not being inclined to put too much into the instrumentation on the vehicle, we chose instead to give it a moderately sensitive sensing ability, while concentrating our resources on making sure the vehicle is robust and reliable enough to withstand a 250-mile off-road trek while protecting the instruments that are onboard. To that end, we designed our vehicle around a set of 58" tall agricultural tires. If all goes well, the sensors should do the trick, if not, and our car takes a bad turn, then we are counting on the large tires and abundant ground clearance to get us through the rough stuff.

## PRIMARY SPONSORS

Laser Technology, Inc., Fabtech Motorsports, Dix

# Rover Systems

**Team Name:** Rover Systems

**Vehicle Name:** C1V1

**Team Leader:** Ted Copperthite

**Organization:** Rover Systems

**Location:** Santa Ana, CA



## In Their Own Words...

C1V1

The Rover Systems C1V1 is a relatively small vehicle with a very low center of gravity for greater stability. It has a fully independent suspension with all-wheel drive and four-wheel steering. Power comes from a 22-horsepower two-stroke engine with an integrated continuously variable automatic transmission. The vehicle uses a 2.6 GHz Pentium 4 processor for the main controller. Our primary sponsor, ESRI, will perform route preprocessing using the latest Geographical Information Systems data. Forward sensing comes from a front-mounted laser measurement system, with short range ultrasonic distance sensors mounted on the sides and rear.



## PRIMARY SPONSORS

ESRI (Redlands, CA), TC Machine (Santa Ana, CA),  
 Mastercraft Welding (Santa Ana, CA), Frontier  
 Technologies (Carson, CA), Quadrant Dynamics  
 (Pasadena, CA), Machined Motorsports (Costa Mesa,  
 CA), Trimble (Sunnyvale, CA), Omnistar, Inc. (Houston,  
 TX), Fox Racing Shox (Watsonville, CA)

# SciAutonics I

**Team Name:** SciAutonics I

**Vehicle Name:** RASCAL (Robust Autonomous Sensor Controlled All-Terrain Land Vehicle)

**Team Leader:** John Porter

**Organization:** SciAutonics, LLC

**Location:** Thousand Oaks, CA



## In Their Own Words...

## RASCAL

The SciAutonics I vehicle, RASCAL, is based on an ATV Corp. Prowler. The Prowler, chosen for its ruggedness and agility, has been extensively modified with actuators to operate the shift, steering, acceleration and braking so that all controls can be manually overridden during testing. SciAutonics is using GPS and INS for waypoint tracking with a suite of sensors including video, LIDAR, ultrasound, and RADAR for road identification and obstacle detection. Our software development will make decisions in real time and make course corrections as necessary. Our philosophy is to win with the combined strength of our superior software and rugged hardware!



## PRIMARY SPONSORS

Rockwell Scientific Company, ATV Corp, Elbit, Rockwell Collins, Rockwell Automation, Auburn University, California Lutheran University, Navcom, Lord Corporation, PNI Corp, Quick Silver Controls, Apex Dynamics, Green Hills Software, SESSA Mfg., OMF, Linear Industries, Elka Suspension, ESRI, BA Technologies, Stardust, Boydgaming, Itronix, Evolution Robotics, GCI Telecom, Motion Tire Motor Sports, Infinite Fabrications, Phoenix International, Airborne I, Bank of America, Enterprise Rent-A-Car (Thousand Oaks)

# SciAutonics II

**Team name:** SciAutonics II

**Vehicle name:** Avidor 2004

**Team leader:** Paul Gunthner

**Organization:** SciAutonics, LLC and Elbit Systems Ltd.

**Location:** Thousand Oaks, CA



## In Their Own Words...

The Elbit Systems–SciAutonics vehicle, Avidor–2004 (Autonomous Vehicle In Deserts & On Roads) is based on an off-road vehicle (“Dune Buggy”) produced by Tomcar, Ltd. of Israel. The Tomcar is tough and proven! We see it as one of the most durable DARPA Grand Challenge vehicles! The Tomcar has been fully and extensively modified. Many additional features include operating actuators and servos for shifting, steering, acceleration and braking. Our vehicle team drivers can manually override the vehicle at anytime for safety and testing.

## AVIDOR 2004



## PRIMARY SPONSORS

Elbit Systems Ltd., SciAutonics LLC, Rockwell Scientific Company, Infinite Fabrication, ESRI, Airborne-1, Rockwell Collins and Rockwell Automation (about a dozen additional sponsors are also contributing to the success of the team to a somewhat smaller extent).

# Team CajunBot

**Team Name:** Team CajunBot

**Vehicle Name:** CajunBot

**Team Leader:** Charles D. Cavanaugh, Ph.D.

**Organization:** The Center for Advanced Computer Studies,  
University of Louisiana at Lafayette

**Location:** Lafayette, LA



## In Their Own Words...

## CAJUNBOT

The vehicle is a six-wheeled all-terrain vehicle used in a variety of settings because of its maneuverability and amphibious capabilities, as well as its ability to climb steep grades. It is powered by a 25 hp twin-cylinder engine capable of driving the vehicle at speeds upwards of 30 mph while sipping fuel, requiring only about 25 gallons of gasoline to go the required 200 mile course. It is also well-suited for control by computer, as it has continuously variable transmission and simple skid steering as a tank by pulling back on the lever in the desired direction. The computer system consists of three Pentium class computers running a mix of operating systems and a bank of electronics for interfacing the computers with the physical world. Sensors include laser rangefinder, sonar and video. The electronics and computers are powered by a Honda 2300 watt generator that shares fuel with the vehicle engine.

## PRIMARY SPONSORS

C&C Technologies, University of Louisiana at Lafayette, MedExpress Ambulance Service, Inc., EMC, Louisiana DOTD, XSens Motion Technologies, K-Tek, Interstate Batteries, Diamond Data Systems, Honda of Lafayette

# Team CalTech

**Team name:** Team CalTech

**Vehicle name:** Bob

**Team leader:** David van Gogh

**Organization:** California Institute of Technology

**Location:** Pasadena, CA



## In Their Own Words...

BOB

Bob is a modified 1996 two-door Chevy Tahoe 4X4. To determine where he is (latitude, longitude) and where he's pointed (pitch, yaw, roll), he'll use a NavCom GPS and a Northrop-Grumman IMU (inertial measurement unit). He'll "see" with two pairs of digital cameras (one for long range and one for short range), a LADAR unit scanning horizontally and mounted on the bumper, and an identical LADAR unit mounted high on the cab and pointing down, scanning the terrain ~40 meters in front of the vehicle. The data from the cab mounted LADAR and stereocameras will be fused with on-board map data to create a map (with obstacles) of the terrain in front of the vehicle. His "brain" will consist of up to eight IBM PCs.



## PRIMARY SPONSORS

Northrop Grumman, IBM, Ahmanson Foundation

# Team CIMAR

**Team Name:** Team CIMAR

**Vehicle Name:** NaviGATOR

**Team Leader:** Dr. Carl Crane, Professor of Mechanical Engineering, University of Florida and CIMAR Director

**Organization:** University of Florida, Center for Machine Intelligence and Robotics and Autonomous Solutions, Inc.

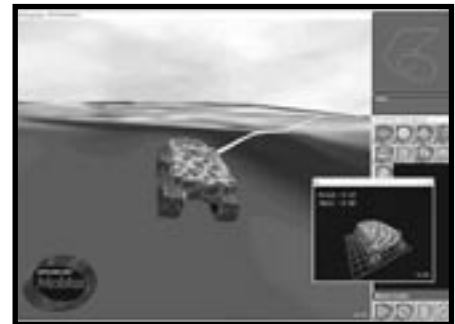
**Location:** Gainesville, FL & Logan, UT



## In Their Own Words...

Team CIMAR, sponsored by Autonomous Solutions Inc., is a cooperative effort between personnel from University of Florida's CIMAR Lab and Autonomous Solutions Inc. NaviGATOR is an automated platform designed using advanced sensors and onboard intelligence to traverse rough, unknown terrain at high speeds. NaviGATOR software is built upon the Future Combat Systems (FCS) mandated Joint Architecture for Unmanned Systems (JAUS). Mobius, developed by Autonomous Solutions Inc. for controlling and monitoring multiple unmanned vehicles, is used for testing prior to the event and initial route planning during the event. This robot represents the future in both commercial and military ground vehicle technologies.

## NAVIGATOR



## PRIMARY SPONSORS

Autonomous Solutions, Inc., Smiths Aerospace, Preco Electronics, NavCom Technologies, Videre Design, The Eigenpoint Company, The Gainesville Raceway, Firestorm Signs and Graphics, The University of Florida

# Team CyberRider

**Team Name:** Team CyberRider

**Vehicle Name:** CyberRider

**Team Leader:** Ivar Schoenmeyr

**Location:** Irvine, CA



## In Their Own Words...

Team CyberRider has developed a propane-fueled chain-driven Sand Rail with a unique air bag suspension. Variable ground clearance allows the CyberRider to maintain speed over rocks and ruts. CyberRider's bank of sensors, including LIDAR and RADAR keep an active watch in front of and around the vehicle, while DGPS and other navigation systems keep the CyberRider on its course. Led by Ivar Schoenmeyr and based in Orange County, California, the vehicle was designed and constructed by a volunteer team of racing professionals, robotics experts, computer science, mechanical and electrical engineers from universities, research institutions and private companies around the country.

## CYBERRIDER



## PRIMARY SPONSORS

Aquatec, GCS Industries, SICK Sensors, UCI Dream Lab

# Team ENSCO

**Team Name:** Team ENSCO

**Vehicle Name:** DAVID

**Team Leader:** Gary Carr

**Organization:** ENSCO, Inc.

**Location:** Falls Church, VA



## In Their Own Words...

DAVID

DAVID is an off-the-shelf ATV, substantially modified to improve stability and obstacle-climbing. It is instrumented with an inertial navigation system using a DGPS, an obstacle detection and avoidance system of laser radar and Doppler radar, and an active system for steering, braking and throttle control. Most members of this company-sponsored, volunteer group are employed by ENSCO, Inc., which contributed significant resources for DAVID in support of the development of innovative technologies.

ENSCO serves the defense, security, transportation, environment, aerospace and intelligent automation industries. ENSCO is an \$80 million, 725-person corporation, headquartered in Falls Church, Va. with offices around the United States and in China.



## PRIMARY SPONSORS

George Mason University Geology Department, National Instruments, The MathWorks, Whelen Engineering, Thomas Jefferson High School for Science and Technology, OmniStar

# Team LoGHIQ

**Team name:** Team LoGHIQ

**Vehicle name:** CCUGV 1.0

**Team leader:** Seth Cabe

**Organization:** Cabe Composites

**Location:** Walden, NY



## In Their Own Words...

Our entry in the Grand Challenge, the CCUGV 1.0, is designed to serve as a modular test platform for the emerging autonomous ground vehicle market. It is a lightweight gasoline-electric hybrid, featuring all wheel drive and a zero turning radius. The race vehicle utilizes a stereo vision system coupled with ultrasonic and laser rangefinders to provide obstacle detection. A digital compass and wheel encoders combine with the high precision differential GPS to provide positional accuracy to less than one foot. A solid state hard drive virtually eliminates the need for isolating the computing system from shocks and vibrations, reducing cost and weight.

## CCUGV 1.0



## PRIMARY SPONSORS

VIA, Hutchinson Industries, Cabe Composites

# Team Phantasm

**Team Name:** Team Phantasm

**Vehicle Name:** Ladibug (Long-range Autonomous Directional Intuitive, Bondry Sensing, Unmanned Ground Vehicle)

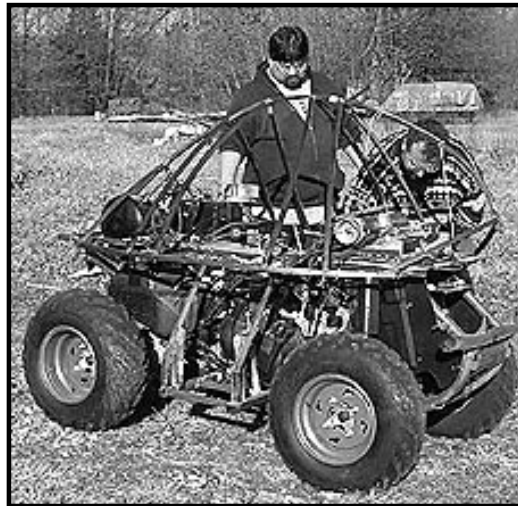
**Team Leader:** Warren Williams & Bill Zimmerly

**Location:** Phantasm Robotics, Inc.

**Location:** Ballwin, MO

## ***In Their Own Words...***

Ladibug is a modified Kawasaki Prairie ATV with self righting ability. Ladibug has a modified fuel bladder that uses radar, sonar and GPS for sensory information, and Zimmerly Knowledge Base as the autonomous software. The vehicle also is equipped with five new technologies that cannot be mentioned at this time.



## LADIBUG



## PRIMARY SPONSORS

Kawasaki, Dipetane, Matricks, Rhino Cad, FMI, Flori Equipment Company, Fuelsafe, Intel, J&B Technologies, U.S.G.S., Viking Memory, Tic-MS, Roboteq, IIDBS, Krumbly Burger of Troy, Mecsoft, Water-Tech Irrigation, and more.

# Team Spirit of Las Vegas (TSOLV)

**Team name:** Team Spirit of Las Vegas (TSOLV)

**Vehicle name:** Auto Quad

**Team leader:** Kent Tiffany

**Organization:** Private Group

**Location:** Edwards, CA



## In Their Own Words...

The TSOLV AUTO QUAD is built on a 2003 Honda 650cc four-wheel drive All Terrain Vehicle with extensive frame modifications to accommodate actuators, video equipment, sensors and computer processors. In order to travel great distances, saddle tanks are mounted on both sides of the vehicle to allow for a minimum range of 300 miles.

The vehicle incorporates three separate electrical systems to provide 12-volt power to the vehicle engine electronics and the navigation computers, and a 24-volt system to power the video recognition components and processors. With a lightweight design, low center of gravity and a four-foot width, the Auto Quad can handle most any terrain and obstacle.

## AUTO QUAD



## PRIMARY SPONSORS

Honda Research and Development, Novatel, Space Imaging, Space Age Controls, Ublox

# Team Terrahawk

**Team Name:** Team Terrahawk

**Vehicle Name:** Terrahawk

**Team Leader:** Todd Mendenhall

**Organization:** Terra Engineering

**Location:** Gardena, CA



## *In Their Own Words...*

TerraHawk is a six-wheeled, 12-foot-long, 2,400-pound hybrid diesel electric vehicle with a Global Positioning System (GPS) sensor. The vehicle has enough intelligence to navigate through dry lake beds and rocky areas of the desert; enough mechanical flexibility to travel rough terrain; lots of smart software; and the capability to travel at speeds averaging 25 miles per hour. TerraHawk uses commercial, off-the-shelf (COTS) hardware, software and sensors. Some key features of TerraHawk include: six-wheel drive, variable height suspension, three articulated segments, distributed data processing system, COTS hardware and software, common software interface approach, NavCom GPS core sensor and wheel tachometers, inclinometers and a magnetometer.

## TERRAHAWK



## PRIMARY SPONSORS

Terra Engineering, LLC

# Team TerraMax

**Team Name:** Team TerraMax

**Vehicle Name:** TerraMax

**Team Leader:** Jim Fravert

**Organization:** Oshkosh Truck Corporation

**Location:** Oshkosh, WI



## In Their Own Words...

TerraMax is a rugged, powerful, 6x6 military vehicle that is suitable for all terrain and environmental operating conditions. This vehicle has proven itself in military operations in Afghanistan and the current Middle East conflict. The vehicle guidance system, developed through collaboration with Ohio State University (OSU), provides fully autonomous operation. The system includes breakthrough technologies featuring advanced sensing, control and situation analysis. TerraMax is able to ford streams, traverse difficult terrain at high speeds, and negotiate significant slopes. The combination of OSU's expertise and Oshkosh's demonstrated competencies, presents the TerraMax as a prime contender in the DARPA Grand Challenge.

## TERRAMAX



## PRIMARY SPONSORS

Oshkosh Truck Corporation (OTC), Ohio State University (OSU)

# Virginia Tech

**Team Name:** Virginia Tech

**Vehicle Name:** Cliff

**Team Leader:** Charles Reinholtz

**Organization:** Virginia Tech

**Location:** Blacksburg, VA



## In Their Own Words...

We are using a gasoline powered four-wheel drive utility vehicle from the Club Car division of Ingersoll-Rand. Computer-controlled DC motors have replaced the conventional throttle, steering, and braking systems. Seven on-board computers provided by National Instruments read and process sensor data to make decisions about speed and heading. The sensor suite includes a differential GPS system integrated with an inertial navigation unit, three scanning laser rangefinders, two radar units and a color video camera. Stored Global Information System (GIS) data is used to find favorable terrain within the course boundaries.

## CLIFF



## PRIMARY SPONSORS

Ingersoll Rand, National Instruments, Honeywell, Sensytech, Novatell, Bodine, Goodyear, Power One, General Motors, Advanced Motion Control, Motion Systems, Inc., Quicksilver, LabVIEW Technical Resource, Intermap, Enercorp, North American Signal Company, Virginia Tech College of Engineering, Virginia Tech Mechanical Engineering Department

# The Golem Group

**Team Name:** The Golem Group

**Vehicle Name:** Golem I

**Team Leader:** Richard Mason

**Location:** Santa Monica, CA



## In Their Own Words...

"Golem" means a creature without a soul, a kind of robot.  
 "Gollum" was a small, slimy creature in *The Lord of the Rings*.  
 There is no connection.

Think of our robot pick-up truck as an indefatigable Rocky,  
 pitted against the glitzy high-rent Apollo Creeds of major  
 research universities and defense contractors.

## GOLEM I



## PRIMARY SPONSORS

Indigo Systems, OmniSTAR USA

# ***The DARPA Grand Challenge***

***Two Hundred Desert Miles***

***10 Hours***

***\$1 Million***

## ***Acknowledgements***

DARPA offers its sincere thanks to all of the government and law enforcement agencies, community groups, businesses, and individuals who offered their guidance and support to help make the Grand Challenge possible.

**Barstow Community College**

**BNSF**

**CALTRANS**

**California Department of Fish and Game**

**California Highway Patrol**

**City of Barstow, California**

**City of Daggett, California**

**Clark County Fire Department**

**Las Vegas Metropolitan Police Department**

**Loma Linda University Medical Center**

**Los Angeles Department of Water and Power**

**Mercy Air**

**NAVAIR Naval Air Warfare Center Weapons Division**

**National Geospatial Intelligence Agency**

**Nevada Department of Transportation**

**Nevada Department of Wildlife**

**Nevada Highway Patrol**

**Primm Valley Resorts**

**San Bernardino County Department of Public Works**

**San Bernardino County Fire Department**

**San Bernardino County Land Use Department**

**San Bernardino County Planning Department**

**San Bernardino County Sheriff's Office, Barstow Station**

**Slash X Café**

**Southern California Edison**

**U.S. Department of the Interior**

**-U.S. Bureau of Land Management**

**-California Bureau of Land Management**

**-Nevada Bureau of Land Management**

**-U.S. Fish and Wildlife Service**

**Union Pacific Police**

**University Medical Center, Las Vegas, NV**

## **DARPA Project Team**

The Grand Challenge has been a true team effort, and the following DARPA leadership and staff are among the many whose hard work and guidance transformed the vision for this history-making program into reality.

### **Dr. Anthony Tether**

Director, DARPA

### **Dr. Robert Leheny**

Deputy Director, DARPA

### **Col. Jose Negron**

Program Manager,  
DARPA Grand Challenge

### **Ron Kurjanowicz**

Chief of Staff, DARPA

### **Dr. Thomas M. Strat**

Deputy Program Manager,  
DARPA Grand Challenge

### **In Association With:**

### **Sal Fish**

CEO/President, SCORE

### **Paul Fish**

Vice President, SCORE

## **DARPA Route Development Team**

Developing the route and procedures, selecting the teams and managing on-site logistics for the Grand Challenge involved a wide range of technical, safety and environmental considerations that were capably handled by experts on the DARPA Route Development Team.

### **Harry Berman**

### **Dr. Art Bruckheim**

### **Bob Copeland**

### **Capt. Christopher Earl**

### **Karen Esposito**

### **Barry Hunt**

### **Larry Jackel**

### **John Jennings**

### **Paul McAree**

### **Mike Perschbacher**

### **Lt. Col. Phil Pioli**

### **Darin Smith**

### **Howard Stears**

### **Algeria Tate**

### **Jan Walker**

### **Col. Otto Weigl**

Thank you to the many DARPA staff members whose efforts helped make the Grand Challenge a possible.



### ***The Grand Challenge Team***

The following contractors supported DARPA staff on behalf of the Grand Challenge.



3rd Street R&D

Beta Analytics International

Booz|Allen|Hamilton

CenGen Inc.

Crossroads Enterprises

Directed Technologies

Ecological Ventures California

EnviroPlus Consulting

General Dynamics Robotic Systems

Georgia Tech

Griffin Technologies

Image Media of Las Vegas

Independent Technical Evaluation Team

Kiva Biological Consulting

Michael Brandman Associates

MindTel, LLC

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SDTV

SRA International

SRS Technologies

Shoemaker Productions

Solid Terrain Modeling

Strat@comm

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Trackside Photography



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